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Ruby Dam, Alder, Montana, Madison County, MT-4

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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

RUBY DAM
ALDER, MONTANA
MADISON COUNTY
MT-4

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PREPARED FOR:

HONORABLE THOMAS L. JUDGE
GOVERNOR, STATE OF MONTANA

MONTANA DEPARTMENT OF
NATURAL RESOURCES AND CONSERVATION
(OWNER)

PREPARED BY:
CH2M HILL
BELLEVUE, WASHINGTON

APRIL 1980

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EXECUTIVE SUMMARY

Under contract with the Seattle District Corps of Engineers, and with representation from the Corps, the State of Montana Department of Natural Resources and Conservation, the Ruby River Water Users Association, Vigilante Canal Water Users Association, and West Bank Canal Water Users Association, CH2M HILL inspected Ruby Dam on May 22, 1979, under the authority of Public Law 92-367. The dam is located on the Ruby River in Madison County, about 6 miles south of Alder, Montana.

This report was compiled from information obtained during an onsite inspection, review of construction plans, and analysis of available hydrologic information. Findings were compared with engineering criteria currently accepted by most private and public agencies engaged in dam design, construction, and operation.

FINDINGS AND EVALUATION

Ruby Dam is owned by the State of Montana and is operated by the Ruby River Water Users Association. The project is used for storage of irrigation waters. The 111-foot-high earth dam impounds 58,400 acre-feet of water at low point of the dam crest elevation 5409.2 feet National Geodetic Vertical Datum (NGVD), previously Mean Sea Level (MSL). On the basis of criteria in the U.S. Army Corps of Engineers Recommended Guidelines for Safety Inspection of Dams (Ref. 1), the project is large in size. The dam is located such that its failure would endanger many lives and cause extensive property damage. However, no dam breach analysis or routing of a dam breach flood was made for the downstream area. The conclusions on possible damage are based on a brief field visit and on engineering judgment. The project is classified as having a high (Category 1) downstream hazard potential. Inspection criteria (Ref. 1) recommend that the spillway design flood (SDF) for a large-sized project with a high downstream hazard potential be the probable maximum flood (PMF). The PMF is the flood expected from the most severe combination of meteorologic and hydrologic conditions that are reasonably possible in the region.

An estimated PMF was developed for the 595-square-mile drainage basin. The PMF resulting from the 72-hour general storm has an estimated volume of 521,000 acre-feet. The spillway has a maximum discharge capacity of 36,000 c.f.s. with the reservoir at the low point of the dam crest, elevation 5409.2 feet NGVD. The routing of the PMF was started assuming the reservoir water surface was at spillway crest, elevation 5392 feet NGVD, with no flashboards. The

routing of the PMF indicates that the dam is overtopped during the PMF when approximately 11 percent of the total flood volume enters the reservoir. Consequently, the project's spillway is seriously inadequate. The dam is constructed of materials that would quickly erode and rapidly fail when overtopped by floodwaters. Such failure would endanger many lives and cause extensive property damage.

In our judgment the Ruby Dam embankment may conform with the stability criteria presented in the inspection guidelines; however, there is insufficient geotechnical information available for an adequate evaluation. On the basis of the field inspection and study of hydrologic data, Ruby Dam does not now conform to Corps guidelines with respect to discharge and/or storage capacities to safely handle the PMF, which could lead to potential loss of life and property destruction. Because the project is incapable of controlling one-half the PMF without overtopping and causing the dam to fail, Ruby Dam is considered unsafe until recommended actions are completed. Urgent action is needed to gain additional storage and/or outflow capacity while studies are underway to safely resolve the situation.

RECOMMENDATIONS

A downstream warning plan for use in the event of possible dam overtopping or structural failure must be immediately developed, tested, and implemented. Provide 24-hour surveillance of the project during peak runoff periods and develop an interim reservoir operating plan to minimize risk until the project can be made safe. Repair the jet pump in the bottom of the gate tower and the cavitation damage on and near the butterfly valve. Seal the joints of the spillway. Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity, and modify the project as studies indicate.

Richard L. Foster
Professional Engineer

PERTINENT DATA

1.	General	
	Federal I.D. No.	MT-4
	Owner	State of Montana, Department of Natural Resources and Conservation
	Operator	Ruby River Water Users Association
	Purpose	Irrigation
	Location	Section 29, T35, R4W Principal Meridian, Madison County, Montana
	Watershed	Ruby River, a tributary to the Jefferson River
	USGS Quadrangle	Ruby Dam, Montana
	Downstream Hazard	Category 1 (High)
2.	Reservoir	
	Elevation at Normal Pool	5392.0 feet NGVD
	Surface Area at Normal Pool	970 acres
	Drainage Area	595 square miles
	Normal Storage (at Spillway Crest, Elevation 5392.0 feet NGVD)	38,850 acre-feet
	Maximum Storage (at low point of Dam Crest, Elevation 5409.2 feet NGVD)	58,400 acre-feet
	Surcharge Storage	19,550 acre-feet

3.	Spillway	
	Location	Right abutment
	Type	Uncontrolled ogee
	Width	125 feet
	Length	361 feet
	Crest Elevation	5392.0 feet NGVD
	Capacity (Reservoir at Dam Crest)	36,000 c.f.s.
4.	Outlet Works	
	Discharge Conduit	90-inch concrete, straight-legged horseshoe
	Length	635 feet
	Gates	At dam center, 72-inch-diameter slide gate upstream of a 72-inch butterfly valve
	Capacity (Reservoir at Dam Crest)	1,750 c.f.s.
5.	Dam	
	Type	Rolled earth with central core
	Length	846 feet
	Crest Width	25 feet
	Design Crest Elevation	5410.0 feet NGVD
	Crest Elevation Low Point	5409.2 feet NGVD
	Hydraulic Height (Crest to Toe)	111 feet

Upstream Slope	1 V on 2 H (crest to elev. 5392 feet NGVD) 1 V on 3 H (below 5392 feet NGVD)
Downstream Slope	1 V on 2 H

CHAPTER 1

BACKGROUND

1.1 INTRODUCTION

1.1.1 Authority and Scope

This report summarizes the Phase I inspection and evaluation of Ruby Dam, owned by the State of Montana.

The National Dam Inspection Act, Public Law 92-367 dated August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to conduct safety inspections of non-Federal dams throughout the United States. Pursuant to that authority, the Chief of Engineers issued "Recommended Guidelines for Safety Inspection of Dams" in Appendix D, Volume 1 of the U.S. Army Corps of Engineers' Report to the United States Congress on "National Program of Inspection of Dams" in May 1975.

The recommended guidelines were prepared with the help of engineers and scientists highly experienced in dam safety from many Federal and state agencies, professional engineering organizations, and private engineering consulting firms. Consequently, the evaluation criteria presented in the guidelines represent the comprehensive consensus of the engineering community.

Where necessary, the guidelines recommend a two-phased study procedure for investigating and evaluating existing dam conditions so deficiencies and hazardous conditions can be readily identified and corrected. The Phase I study is:

(1) A limited investigation to assess the general safety condition of the dam.

(2) Based upon an evaluation of the available data and a visual inspection.

(3) Performed to determine whether any needed emergency measures and/or additional studies, investigations, and analyses are necessary or warranted.

(4) Not intended to include extensive explorations or analysis or to provide detailed alternative correction recommendations.

The Phase II investigation includes all additional studies necessary to evaluate the safety of the dam. Included in

Phase II, as required, should be additional visual inspections, measurements, foundation exploration and testing, material testing, hydraulic and hydrologic analyses, and structural stability analyses.

The authority for the Corps of Engineers to participate in the inspection of non-federally owned dams is limited to Phase I investigations, except for extreme emergency situations. In these cases the Corps may proceed with Phase II studies, but only to the extent needed to answer serious questions relating to dam safety that cannot be answered otherwise. The two phases of investigations outlined above are intended only to evaluate project safety and do not encompass in scope the engineering required to perform design or corrective modification work. Recommendations contained in this report may be for either Phase II safety analyses or detailed design study for corrective work.

The responsibility for implementing of these Phase I recommendations rests with the dam owner and the State of Montana. It should be noted that nothing contained in the National Dam Inspection Act, and no action or failure to act under this Act shall be construed (1) to create liability in the United States or its officers or employees for the recovery of damage caused by such action or failure to act or (2) to relieve an owner or operator of a dam of the legal duties, obligations, or liabilities incident to the ownership or operation of the dam.

1.1.2 Purpose

The purpose of the inspection and evaluation is to identify conditions that threaten public safety, so that they may be corrected promptly by non-Federal interests.

1.1.3 Inspection

The findings and recommendations in this report were based on visual inspection of the project, a detailed review of available plans and specifications, and design analyses. Inspection procedures and criteria were those established by the Recommended Guidelines for Safety Inspection of Dams (Ref. 1).

Personnel present during the May 22, 1979, inspection include:

Larry Tegg, State of Montana Department of Natural Resources and Conservation

Tom Ferguson, State of Montana Department of Natural Resources and Conservation

R. D. Eckerlin, Geologist, Corps of Engineers

Lowell Sauerbier, Ruby River Water Users Association

Jack Fenton, Vigilante Canal Water Users Association

N. D. Conklin, Vigilante Canal Water Users Association

Loren Wheeler, Vigilante Canal Water Users Association

Jerry Burke, West Bank Canal Water Users Association

Mike Moran, Dam Operator

CH2M HILL personnel who participated in the field inspection and contributed to this report are:

Miles C. Bubenik, Geotechnical Engineer, Team Leader

Jerry Jacksha, Geotechnical Engineer

Loren Bottorff, Hydrologist/Hydraulics Engineer

Mons Hoyrup, Structural Engineer

This report has been reviewed by the State of Montana Department of Natural Resources and Conservation and the Vigilante and West Bench Canal Companies. Their comments are included in the Appendix.

1.2 DESCRIPTION OF PROJECT

1.2.1 General

Ruby Reservoir and Dam are located on the Ruby River, a tributary of Jefferson River, in Madison County, Montana, approximately 6 miles south of the town of Alder (see Plate 1). The dam's Federal identification number is MT-4, and it is listed on the National Dam Inventory. The 111-foot-high dam impounds 58,400 acre-feet at the low point of the dam crest, elevation 5409.2 feet NGVD. Based on a visual reconnaissance and engineering judgment, residential homes, property, and agricultural land could be affected by a sudden breach of the dam. On the basis of this information and in accordance with the recommended guidelines, the project is classified as large in size, and the downstream hazard potential is high (Category 1).

Principal use of the 38,850 acre-feet (normal pool) reservoir is irrigation storage. Although the project is owned by the State of Montana, operation and maintenance are performed by the Ruby River Water Users Association, the Vigilante Canal Water Users Association, and the West Bank Water Users Association.

The 125-foot-wide spillway channel is located on the right abutment, as shown in Photo 1 and Plate 2. A 90-inch horse-shoe-shaped outlet with two 72-inch-diameter gates and gate controls at the dam crest are used for irrigation releases.

1.2.2 Regional Geology and Seismicity

The geology and seismicity of the Ruby Dam reservoir area were addressed in a memorandum by R. D. Eckerlin (Ref. 2). Portions of the following are taken from that memorandum.

Several short mountain ranges dominate the topography in the Ruby River drainage area. The Ruby River lies in a structurally controlled valley between the Ruby and Greenhorn Ranges. Precambrian metamorphic gneisses and schists of various compositions form the cores of both these ranges. A rib of Precambrian rocks extends across the Ruby Valley at Ruby Dam, connecting the two ranges.

The Ruby Reservoir is floored with Tertiary and Quaternary sediments composed of silt, sand, and gravel detritus from the bordering mountains.

Most of the major structural features in the area, including trends of faulting, fold axes, and doming, were formed during the Laramide Orogeny that began during the late Cretaceous and ended before the middle Eocene. Several north to northeast trending faults situated in the Greenhorn Range are located about 6 to 9 miles southeast from Ruby Dam. Three northwest trending faults associated with the Laramide Orogeny occur in the Ruby Range within 7 miles north and west of Ruby Dam.

Below the dam, Ruby River flows for about 2 miles through a narrow canyon that was cut out of metamorphic rock. The floor of the canyon is mantled with recent stream alluvium. In this segment, the river gradient is approximately 20 feet per mile. After the river leaves the canyon, it meanders through a wide valley for several miles and then flows into the Jefferson River, which is located 1-1/2 miles north of Twin Bridges, Montana.

The dam lies in a zone that is susceptible to major earthquake damage. Algermissen (Ref. 3) indicates this zone

could expect a maximum Modified Mercalli intensity X event, or equivalent magnitude 7.3 event, in the next 100 years. A probability estimate of 0.4 g horizontal bedrock acceleration has a 90 percent likelihood of not being exceeded in 50 years. It is estimated that the dam experienced a 0.2 g bedrock acceleration during the 1959 Hebgen Lake Earthquake.

The Guidelines Seismic Zone Map (Ref. 1) shows the site is in Seismic Zone 3, which has the potential for major earthquake damage. Although the Zone Map is based on a known distribution of damaging earthquakes, it does not necessarily reflect accurate or adequate seismic design parameters for this site.

1.2.3 Site Geology

This discussion of site geology is taken in part from the R. D. Eckerlin memorandum (Ref. 2).

The dam site was explored by 28 drill holes, all of which were extended to bedrock. An additional 27 drill holes were used to explore the spillway and low-level conduit areas.

Precambrian metamorphic bedrock underlies the site. Both abutments consist of a complex metamorphic assemblage chiefly comprising dolomitic marble, chert, quartzite, conglomerate, and granitic gneiss.

The spillway is located at the right abutment and consists of a concrete-lined channel excavated through metamorphic bedrock. The 90-inch-diameter, low-level outlet consists of a concrete-lined tunnel excavated through metamorphic bedrock in the left abutment.

Various tertiary deposits are exposed in the slopes around the reservoir. These materials are alluvial fan deposits, lakebed sediments, windblown silts, and volcanic debris, including ash. Slopes are gently inclined and are nearly void of trees. Wave erosion of the reservoir shoreline is present.

1.2.4 Design and Construction History

The Ruby Dam project was designed by the State Water Conservation Board, Helena, Montana. Construction began in 1936 and was completed in 1938. Original drawings and project specifications are on file with the State of Montana. Plates 2, 3, 4, 6, 7, and 8 were developed from the construction drawings. Design data, detailed construction as-built drawings, and information on construction control testing were not available for our review.

CHAPTER 2

INSPECTION AND RECORDS EVALUATION

2.1 HYDRAULICS AND STRUCTURES

2.1.1 Spillway

The spillway for Ruby Dam is located in the rock of the right abutment. The unlined approach channel to the uncontrolled concrete ogee crest is short and unobstructed. The crest discharges to a concrete chute that ends at a stilling basin near the creek level.

The concrete crest is formed to an ogee shape with an approximately 12-foot design head. The apex of the spillway crest is at elevation 5392 feet NGVD, 17.2 feet below the low point on the dam crest. Pipes on 4-foot centers are embedded along the apex of the spillway crest for the installation of flashboards. Flashboards were installed to elevation 5392.9 feet NGVD at the time of the inspection. The spillway crest is 125 feet wide and contains no piers. The right spillway abutment is rounded at a 7.23-foot radius, and the left spillway abutment is rounded at a 24-foot radius. Downstream of the crest, the spillway chute narrows to a 75-foot width within a distance of approximately 180 feet (Plate 3). The chute continues for another 180 feet and ends at a stilling basin. The slope of the chute gradually changes from 0.155 downstream of the crest to 0.37 at the stilling basin (Plate 4). The floor of the stilling basin is 3 feet lower than the channel leaving the basin. Water in the basin prevented detailed inspection of the concrete. Minor sloughing of rock at the downstream right side of the stilling basin has occurred. However, the downstream channel is not eroding or backcutting.

The stilling basin size appears inadequate to effectively dissipate energy from spillway discharge. However, as the stilling basin is located well downstream of the dam and on bedrock, adverse effects are expected to be minor.

The spillway chute concrete is cracked and spalled in some areas (Photos 2 and 3). Floor slabs and walls showed some differential movement at the expansion joints. Water marks (Photo 4) on the chute walls downstream of the expansion joints indicated that the joints cause some disturbance to low spillway flows. This disturbance may not cease with increased discharge, and the chute walls may be overtopped by flows significantly less than maximum spillway discharge.

Overtopping flows may erode the dam embankment and endanger its safety. Additionally, the irregular joints may result in cavitation damage to the spillway chute concrete.

The spillway rating was developed, with the flashboards removed, by using the weir head-discharge relationship with head-dependent discharge coefficients varying from 3.14 to 4.03. The coefficients are for an ogee crest with a weir height to design head ratio of 0.42. The maximum discharge capacity of the spillway was estimated to be 36,000 c.f.s., with no flashboards and with the reservoir at the top of the dam, elevation 5409.2 feet NGVD. However, the chute walls may be overtopped at flows significantly less than this discharge because of the disturbance that occurs at the expansion joints (see Photo 4). The arrangement of the flashboards that existed during the inspection reduces the maximum discharge by 10 percent. The discharge rating curve, with flashboards removed, is presented on Plate 5.

2.1.2 Outlet

The outlet works for Ruby Dam is located in the left abutment of the dam. The intake structure could not be examined at the time of the inspection because of the high reservoir level, but construction plans show it as a pair of slightly converging wing walls covered by a trashrack. The concrete conduit (Photo 5) is a 90-inch-diameter, straight-legged horseshoe section approximately 635 feet in length (Plate 6).

A gate tower is located about 400 feet downstream from the intake structure near the centerline of the dam. The conduit slope (Plate 7) is 0.0025 from the intake structure to the gate tower and 0.005 from the gate tower to the outlet structure. The invert of the conduit at the outlet structure is 5298 feet NGVD, 111 feet below the low point on the dam crest. The controls for the 72-inch-diameter emergency slide gate and the 72-inch-diameter operating pivot butterfly valve are located at the top of the tower. The valves are operated by an electric pipe-threading tool, but they can also be operated by hand crank. The gate tower is covered by a locked gatehouse. Members of the Water Users Association indicated that the jet pump (which functions to keep the gate tower dewatered) at the bottom of the gate tower had not been operating properly. Corrosion of metal appurtenances could result if water is allowed to collect in the bottom of the tower. The exit structure at the toe of the dam consists of a pair of slightly diverging wing walls. A Cipolletti weir is located approximately 200 feet downstream of the outlet structure, at elevation 5302.5 NGVD. The downstream channel contains much rock and is not eroding or backcutting.

The operating valve was closed for the inspection, and the conduit was entered from the downstream portal. The conduit contained minor cracking. Some water was seeping through the construction joints. The seats on the operating valve were leaking, and it was not possible to get within 20 feet of the valve. The emergency gate was then closed, and the leakage stopped.

Minor cavitation damage was observed on the top deflector of the operating valve and just downstream of the jet pump discharge. Areas previously treated with epoxy steel appeared to be in good condition. A steel liner extends about 10 feet downstream of the operating gate and contains minor corrosion.

The discharge rating for the outlet works was developed with both valves fully open. A Manning's "n" of 0.013 was used to estimate friction losses with the conduit flowing full. The maximum discharge capacity of the outlet works, with the reservoir at the top of dam, elevation 5409.2 feet NGVD, was estimated to be 1,750 c.f.s.

2.1.3 Freeboard

Because the dam overtops during the probable maximum flood (PMF: see paragraph 2.2.4), there is no freeboard. The vertical distance between the low point on the dam and the reservoir level at the time of the inspection was 18.4 feet. The spillway crest is 17.2 feet below the low point on the dam crest, but flashboards currently are installed to 0.9 feet above the spillway crest. The crest of the dam varies 1.5 feet in elevation over its 846-foot length. The effective fetch for wind-generated waves is about 1 mile, and wave runup on the embankment is estimated to be about 5 feet. Although the dam will overtop during the PMF, the vertical distance between the dam crest and the normal reservoir level is adequate to prevent overtopping of the embankment by wind-generated waves.

2.2 HYDROLOGY, CLIMATOLOGY, AND PHYSIOGRAPHY

2.2.1 General

The climate of the area is continental in nature, characterized by warm summers and cold winters. A climatological station (Alder 17S) is located in the drainage basin at elevation 5850 NGVD, but records have not been kept long enough for normal values to be published by the National Weather Service. A climatological station is located at Lakeview (elevation 6710 feet NGVD), approximately 16 miles southeast of the basin boundary.

Mean annual precipitation at the Lakeview station is 20.5 inches, with 42 percent falling in April through July. Mean February precipitation is 1.19 inches and mean June precipitation is 3.28 inches. Mean annual precipitation in the Ruby Dam drainage basin is probably near 16 inches. Mean annual temperature at Lima (26 miles southwest of the basin boundary, elevation 6273 feet NGVD) is 39 degrees Fahrenheit (F). Mean January temperature is 16.5 degrees F and mean July temperature is 62.1 degrees F.

Temperatures on the Ruby Dam drainage basin are probably similar to those at Lima. Summer temperatures can exceed 100 degrees F, and winter temperatures can dip well below 0 degrees F. Winters have few extended cold spells; periods of warm, "chinook" winds occur between cold spells.

The drainage basin area for Ruby Dam is 595 square miles and is roughly oval in shape. The basin elevations range from 5,400 feet at the dam to 10,545 feet at Black Butte, on the southeastern drainage boundary. The basin is mountainous and about 40 percent forested. The Ruby River, the main inflow stream to the reservoir, has many tributaries. A USGS stream-gaging station is located upstream of the reservoir. The station, with 42 years of records, recorded a maximum flow of 1,670 c.f.s. in 1970. A second station, with 18 years of records, is located just downstream of the dam.

2.2.2 Reservoir Storage and Spillway Discharge

The reservoir has a surface area of 970 acres and a storage of 38,850 acre-feet at spillway crest, elevation 5392 feet NGVD. Approximately 19,550 acre-feet of surcharge storage is available in the reservoir between the spillway crest and the dam crest. The spillway discharge with the reservoir at the dam crest is 36,000 c.f.s., or about 2,980 acre-feet per hour.

2.2.3 Estimated Probable Maximum Flood

The inspection guidelines recommend that the spillway design flood (SDF) for a project of this type be the probable maximum flood (PMF). The PMF is defined as the flood expected from the most severe combination of critical meteorologic and hydrologic conditions that is reasonably possible in the region. An estimate of the PMF was made during this dam safety analysis and was routed through the reservoir.

The procedure contained in the U.S. Weather Bureau's Technical Paper 38 (Ref. 4) was used to compute the probable maximum precipitation (PMP). This storm, for the 595-square-

mile basin, produces 8.4 inches in 6 hours and 13.3 inches in 24 hours. The 72-hour precipitation was estimated to be 16.1 inches.

A triangular unit hydrograph for a 1-hour rainfall duration was developed for the drainage basin by procedures outlined in Design of Small Dams (Ref. 5). A curvilinear fit of the triangular unit hydrograph was used. The PMP was applied to the unit hydrograph by means of the computer program, HEC-1 (Ref. 6). This estimate of the PMP produced a flood with a volume of 521,000 acre-feet.

2.2.4 Flood Routing

The PMF was routed through the reservoir by using the computer program HEC-1 (Ref. 5). The reservoir level was assumed to be at the spillway crest, with no flashboards, at the beginning of the PMF. Frozen ground and no infiltration losses were assumed during the entire flood. The outlet works was assumed to be fully open during the entire flood.

The routing shows that the dam will be overtopped during the PMF when approximately 11 percent of the total flood volume enters the reservoir. Floods much smaller than the PMF could overtop and fail the dam. Because the dam overtops at such a small percentage of the PMF, no routings were made with the spillway flashboards in place.

2.3 GEOTECHNICAL EVALUATION

2.3.1 Dam Embankment

The 111-foot-high zoned earth, gravel, and rockfill embankment is 846 feet long and has a crest width of 25 feet. The upper 10 feet of the upstream slope is 1 V on 2 H; below that it changes to 1 V on 3 H. The downstream slope is 1 V on 2 H. Plate 8 shows that the slope between the upstream selected clay and loam impervious zone and the central clay, loam, sand, and gravel zone is 1 V on 1 H. The division between the downstream sand, gravel, and rockfill zone and the central zone is 1 V on 1 H. The upstream impervious zone is founded on bedrock.

The specifications limited soil and rock type by size and percent of soil and rock; no laboratory tests on materials used in the construction are now available. The placement method for embankment materials specified 6-inch horizontal lifts, compacted with a toothed roller generating 1,150 pounds per tooth. Embankment materials, if overtopped by floodwaters, would rapidly erode and fail the dam.

Embankment materials were obtained from spillway, tunnel, and cutoff excavations, as well as onsite quarries and borrow pits.

Visual inspection indicated that the downstream embankment slope is rockfill and has a sparse covering of brush (Photo 7). Rockfill is segregated with the larger pieces at the toe, probably the result of dumping from the crest. No erosion, irregularities, slumps, or cracks were present on the dam crest or slopes.

Information from drill logs indicates that the 90-inch outlet conduit was excavated in rock. The construction plans show that the conduit was concrete lined throughout. Four concrete cutoff collars are shown under the upstream cut and cover section of the conduit.

The upstream slope (Photo 6) is adequately protected from erosion caused from wave attack by a 2.5-foot thickness of riprap and 2-foot thickness of sand and gravel bedding (Plate 8). Minor wave erosion has occurred at the right abutment near the spillway, where riprap was removed for vehicle access to the reservoir.

2.3.2 Foundation Conditions, Seepage, and Drainage

Both abutments of the dam are metamorphic rock. Specifications state that cutoff grooves were to be excavated in the abutments and backfilled with "selected" fill containing no more than 10 percent gravel or rock. The actual gradation of the "selected" fill is unknown.

The extent of the foundation preparation is unknown; however, the specifications state, "the material lying below the line of stripping under the upstream one-third of the embankment, under the rock section of the embankment, and on the remainder of the side abutments shall be excavated to firm bedrock." Boring logs show that the depth to bedrock is about 6 feet in the highest portion of the embankment and excavation of the overlying soils should not be a difficult task.

Specifications permitted backfilling the impervious zone cutoff by the puddle method (12-inch layers of earth, sand, and gravel deposited in water and thoroughly worked with shovels) or by compacting earth in 6-inch lifts; the method actually used is unknown.

As specified, preparation of the remaining foundation not taken to rock consisted of stripping unsuitable material and scarifying and compacting the surface a minimum depth of 8 inches.

During the inspection, no seepage or erosion from past seepage was observed on the embankment or abutment contacts. At the base of the spillway, seepage was emerging from a transverse construction joint immediately above the stilling basin and from a 6-inch pipe drain located on centerline at Station 3+25 (see Plates 3 and 4). Flow from the construction joint suggests that the drainage system is plugged in this area. The Water Users Association believed this seepage was from a spring that existed prior to construction. This seepage is unrelated to embankment stability, in that it is apparently occurring in the jointed rock. However, the seepage could create problems leading to instability of the spillway base slab, especially during high flows immediately following cold weather, if the seepage exits become frozen.

The dam embankment contains no known internal drains or piezometers.

2.3.3 Stability

Guidelines for dam safety inspections (Ref. 1) recommend that stability analyses be on file for all dams in the high-hazard category. Based on a review of available information, it is our preliminary judgment that the embankment stability may conform with the Corps guidelines; however, sufficient information is not currently available to accurately evaluate stability.

2.4 PROJECT OPERATION AND MAINTENANCE

The facility is owned by the State of Montana, Department of Natural Resources and Conservation (DNRC) and is operated by the Ruby River Water Users Association. Information on operation and maintenance was obtained from discussions with members of the Water Users Association, as formal project operation and maintenance programs for the dam do not exist. Mr. Moran, the dam operator, lives just downstream of the dam.

2.4.1 Dam

Maintenance of the dam is performed as required. Cavitation damage at the butterfly valve is periodically repaired with epoxy steel. In general, the project appeared to be well maintained. The improper functioning of the jet pump and the open expansion joints of the spillway show two areas lacking recent maintenance.

The State of Montana DNRC conducts annual inspections of the facility and makes appropriate recommendations for maintenance and repairs.

2.4.2 Reservoir

The dam operator lives just downstream of the dam and visits it often. The water rights on the Ruby River have been adjudicated and a minimum flow must be released from the dam at all times. The Ruby River Water Users Association has been experimenting with an operation plan developed by the U.S. Soil Conservation Service (SCS) that uses snow survey and weather information to maximize flood storage and irrigation benefits. This increased manipulation of the river flows has caused some objections from downstream landowners. The spillway normally operates for a short time each year and flashboards are often used to increase storage.

2.4.3 Warning System

There is no formal warning plan for use in the event of impending dam failure.

CHAPTER 3

FINDINGS AND RECOMMENDATIONS

3.1 FINDINGS

Visual inspection of the dam, supplemented by analysis of the project in terms of the recommended guidelines' performance standards, resulted in the following findings.

3.1.1 Size, Hazard Classification and Safety Evaluation

In accordance with inspection guidelines (Ref. 1), Ruby Dam is classified as large in size and has a high downstream hazard potential rating. The recommended spillway design flood for this project is 100 percent of the PMF. Because the project can safely handle only 11 percent of the PMF without overtopping and causing the dam to fail, the spillway is seriously inadequate, and Ruby Dam is considered unsafe until the recommended actions (Section 3.2) are completed.

3.1.2 Embankment Dam

A visual inspection of Ruby Dam revealed no longitudinal or transverse cracking, as well as no embankment, abutment contact, or toe seepage.

The upstream and downstream slopes were uniform with no irregularities or slumps. The dam crest varies 1.5 feet in elevation over its 846-foot length. Both slopes support a sparse covering of small brush. Riprap on the upstream slope adequately protects against erosion, with the exception of the area near the spillway where the riprap was removed for vehicle access. The freeboard maintained during normal pool levels is adequate to prevent wind-generated waves from overtopping the dam crest.

No stability analysis of the dam embankment is on file. Materials actually used in embankment construction are unknown. In our preliminary judgment, embankment stability may conform to the recommended guidelines; however, sufficient information is not now available to accurately determine stability. Because of the high downstream hazard potential, a stability analysis needs to be performed and maintained on file.

3.1.3 Spillway and Reservoir Capacity

The reservoir has a surface area of 970 acres and a storage of 38,850 acre-feet at spillway crest, elevation 5392 feet NGVD. Approximately 19,500 acre-feet of surcharge storage is available in the reservoir between the spillway crest and the dam crest. The discharge of the spillway, with the reservoir at the dam crest, is 36,000 c.f.s.

The concrete of the spillway chute contained some cracking and spalling. The drainage system beneath the concrete spillway floor slab is constructed to discharge into the stilling basin. Seepage emerging from the transverse expansion joint suggests the drainage system is plugged in this area and could lead to instability of the spillway floor slab during sustained high spillway flows. Floor slabs and walls showed some differential movement at the expansion joints. Water marks on the chute walls downstream of expansion joints indicate that the joints cause some disturbance of the flow. This disturbance may not cease with increased discharge, and the chute walls may be overtopped by flows significantly less than maximum spillway discharge. Overtopping of the left spillway wall could damage the earthfill dam.

Additionally, the irregular joints may result in cavitation damage to the spillway chute concrete.

3.1.4 Outlet Works

The seats on the operating valve were leaking until the emergency gate was closed. Minor cavitation damage was observed on the top deflector of the operating valve and just downstream of the jet pump discharge. Areas previously treated with epoxy steel appeared to be in good condition.

3.1.5 Operation and Maintenance

The State of Montana DNRC conducts annual inspections of the facility and makes recommendations for maintenance and repairs. The Ruby River Water Users Association is responsible for operation and maintenance and employs a dam operator who lives below the dam. Maintenance of the dam is performed as required. Cavitation damage at the butterfly valve is periodically repaired with epoxy steel.

In general, the project appeared to be well maintained. The improper functioning of the jet pump and the open expansion joints of the spillway show two areas lacking recent maintenance. The water rights on the Ruby River have been adjudicated, and a minimum flow must be released from the dam at all times. The Ruby River Water Users Association

has been experimenting with an operation plan developed by the SCS that uses snow survey and weather information to maximize flood storage and irrigation benefits.

3.2 RECOMMENDATIONS

1. Immediately develop, implement, and periodically test an emergency warning plan for use in the event of impending dam overtopping or structural failure.

2. Provide 24-hour surveillance of the project during peak runoff periods.

3. Develop an interim reservoir operating plan to minimize risk until the project is made safe.

4. Permanently remove flashboards and prevent all obstructions to spillway flow.

5. Repair the jet pump in the bottom of the gate tower.

6. Repair cavitation damage on and near the butterfly valve.

7. Provide additional drain holes and/or drainage for positive seepage exit, and fill the expansion joints of the spillway with an elastic cement.

8. Inspect the outlet tunnel upstream of the control valves and repair as required.

9. Replace riprap on the upstream slope near the right abutment when it has been removed for vehicle access.

10. Determine whether the unstable water surfaces in the spillway indicated (see Photo 4), at the expansion joints, persist at high flows, and if there is a potential for cavitation damage. These determinations should be made by a qualified hydraulic engineer. If it is confirmed that the instability does persist and flow will overtop the spillway walls, provide protection to that portion of the dam embankment adjacent to the left spillway wall, and evaluate the need for repair of cavitation damage.

11. Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity, and modify the project as studies indicate.

12. Conduct and place on file stability and seepage analyses of the dam embankment. We recommend that these analyses be performed by a qualified geotechnical engineer and

be based on: seismic and static loading conditions; in situ strength properties of the embankment, foundation, and abutment materials; and phreatic surface conditions. Determine the seismic loads based on a seismic assessment of the area, and evaluate the project's response to a seismic event. Establish the material strength properties by drilling and sampling with laboratory testing as appropriate, and determine the phreatic surface by installing and monitoring piezometers. If studies show the dam does not conform to inspection guideline stability recommendations, provide engineering assistance and modify project to provide conformance.

13. Periodic inspections of the Ruby Dam should be conducted at least once every 5 years by engineers experienced in dam design and construction. In addition, inspect the dam immediately if a moderate-sized earthquake occurs within proximity of the project.

REFERENCES

1. U.S. Army Corps of Engineers, Office of the Chief of Engineers Report to the U.S. Congress, National Program of Inspection of Dams, Vol. 1, Appendix D, "Recommended Guidelines for Safety Inspection of Dams," Washington, D.C., Department of the Army, May 1975.

2. Richard D. Eckerlin, U.S. Army Corps of Engineers, Memorandum on Ruby Dam Inspection, August 1979.

3. S.T. Algermissen and D.M. Perkins, "A Probabilistic Estimate of Maximum Accelerations in Rock in the Contiguous United States," Bulletin, U.S. Department of the Interior, Open file report, U.S. Geological Survey, No. 76-416, 1976.

4. U.S. Weather Bureau, Technical Paper 38, Generalized Estimates of Probable Maximum Precipitation for the United States West of the 105th Meridian, Washington, D.C., 1960.

5. U.S. Bureau of Reclamation, "Design of Small Dams," 2nd Edition, 1974.

6. U.S. Army Corps of Engineers, Hydrologic Engineering Center, HEC-1 Flood Hydrograph Package, Davis, California, January 1973.

APPENDIX

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
WATER RESOURCES DIVISION

THOMAS L. JUDGE, GOVERNOR

32 SOUTH EWING

STATE OF MONTANA

(406) 449-2872

HELENA, MONTANA 59601

March 26, 1980

Ralph Morrison
Department of the Army
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, Washington 98124

Dear Mr. Morrison:

The Department of Natural Resources and Conservation has reviewed the final draft report on the Ruby River Dam (MT-4). We concur with the findings and recommendations and feel that the report satisfies the criteria for the Phase I evaluation. Minor comments have been discussed with your staff and we understand that these will be included in the final report.

We sent copies of the report to the Ruby River Water Users Association and their comments are enclosed.

Thank you for this opportunity to review and comment on the final draft report for this project.

Sincerely,

Richard L. Bondy

Richard L. Bondy, P.E.
Chief, Engineering Bureau
(406) 449-2864

RB:LT:mb
Enclosure

"AN EQUAL OPPORTUNITY EMPLOYER"

SCHULZ, DAVIS & WARREN
LAWYERS

LEONARD A. SCHULZ
CARL M. DAVIS, P.C.
JOHN WARREN, P.C.

RECEIVED
MAR 19 1980
MONT. DEPT. OF NATURAL RESOURCES & CONSERVATION

122 EAST GLENDALE STREET
P. O. BOX 28
DILLON, MONTANA 59725
AREA CODE 406
683-2363

March 5, 1980

Mr. Lawrence H. Teeg
Dam Safety Section
Engineering Bureau
Department of Natural Resources
32 South Ewing
Helena, Montana 59601

RE: Dam Safety Inspection Report
Ruby Dam dated November 19, 1979

Dear Mr. Teeg:

Subsequent to receipt of your letter of February 4, 1980, with copies of the above Dam Safety Inspection Report, the directors of the Ruby River Water Users Association, Vigilante Canal Company, and West Bench Canal Company met and reviewed your report and offer the following comments in connection therewith. We were unable to complete the comments by February 25th as suggested, however, understand that attorney Carl M. Davis talked with your office and additional time to comment was extended.

First and foremost, of course, the water users are probably more concerned than anyone else about the safety of the dam inasmuch as their families live below the dam and receive the water therefrom, and further have invested their lives' earnings in reliance upon receiving water from the dam as provided in their contract with the state of Montana. They, of course, feel they have every right to expect that the state did not build an unsafe dam and, of course, wouldn't be living below the dam if they felt that their lives and property were in jeopardy. The water users associations have fully complied with all maintenance that the State has requested through their engineering branch throughout the history of the dam, to the best of anyone's present knowledge, and can find nothing in their files to indicate to the contrary. Any disruption of the delivery of storage water to the water users would be completely devastating as your office knows that there is approximately 30,000 acres of land that depend on this storage water to some degree and it is critical to the operation of each ranch.

Dam Spillway: The dam spillway of approximately 12 feet in height and 125 feet in width is capable of spilling 36,000 cfs which would be added to the 1750 cfs going through the outlet. In 42 years of records, the report indicates that the maximum ever spilled was 1670 cfs. As a matter of fact, I am sure your department has studied and is aware of the fact that the spillway provision on this dam compares favorably with any state dam in the state of Montana and with many federal dams in the state, including earthfilled dams, with much larger drainage areas. To recommend that a spillway or dam be built to store the possible maximum flood is completely ridiculous as far as irrigation dams is concerned and would make any such dam economically unfeasible.

Probable Maximum Flood: The report bases its data on a theoretical probable maximum flood putting out 16.1 inches over each acre of a 595 square mile drainage basin on frozen ground. Although such a storm may be theoretically possible on computers, there is no historical or scientific evidence that a storm of this magnitude has ever occurred in southwestern Montana. Although we realize that records are entirely ignored in making these types of computations, they are certainly the best evidence of what has occurred and other scientific, geological, and archeological evidence of a more scientific nature will disclose that such an occurrence has never occurred if they cared to study the same. To say there would be this much water on each square mile is also contrary to what happens in the real world without any infiltration at all of the water and considering that the report further says that 40% of the area is forested. The Ruby Dam impounds 58,400 acre feet of water and the possible maximum storm is 525,000 acre feet, so it would be very obvious that if this storm ever occurred, the damage to life and property would occur with or without the Ruby Dam and any removal or breach of the Ruby Dam would have little effect. The report says they made no study or computations as to what would happen to life and property without the dam based on their p.m.f. A study should be made as to what the result would be if such a storm did occur whether the dam is there or not to determine what difference it would make. There is little doubt that any break in the dam would cause damage, however, there is equally little doubt that if the projected storm occurred, the damage would be there whether you had the Ruby Dam or not. The water users would not consider the removal of any portion of the dam unless there were some concrete evidence, rather than theoretical, computerized projections, that a storm of this magnitude would be reasonably possible in the region.

Earthquakes: This dam has withstood the earthquake at Hebgen Lake and a more recent earthquake within the last 30 days without any visible evidence of disturbance of any kind, and there is no evidence that the dam is susceptible to major earthquake damage that might reasonably occur.

Recommendations: In response to the recommendations on page 31, paragraph 3.2, we comment as follows:

1. We concur with the emergency warning plan as outlined.

2. We do provide 24 hour surveillance of the project during peak runoff periods. As a matter of fact, the dam tender lives at the dam and inspects it daily, not frequently, as set out in the report.

3. We concur in the development of an interim reservoir operating plan subject to our various boards' approvals.

4. We do not concur in permanently removing the flash boards in the spillway. This would cost 1,000 acre feet which is valuably needed in dry years for the water users. We would consider a plan whereby the flash boards would be removed in the event a rain of the magnitude projected by the p.m.f. should occur after, say, the first 24 hours on frozen ground and no penetration.

5. The check pump in the bottom of the gate tower has been repaired and we concur it should be kept in repair.

6. The cavitation damage on or near the butterfly valve has been repaired and we concur it should be maintained in good repair.

7. We would need more engineering information before we could comment or concur with recommendation #7. We do not understand what practical use the drain holes would be if you had the p.m.f. that is projected, however, I am sure your engineering department will be able to advise us in this regard.

8. We concur with the inspection of the outlet tunnel and to make such repairs to the control valves as are required.

9. We concur with recommendation #9 and believe that it has been completed.

10. We concur with recommendation #10 and would think that the state has qualified hydraulic engineers that could handle this matter on a state project.

11. As far as further engineering studies are concerned, we would have no comment in view of the fact we are not engineers and would not feel that this is part of the contractual obligation of the water users. We agreed to pay maintenance of the structure that we are purchasing the water from but certainly do not concur to pay for detailed engineering studies on the state dam. We do not concur with any modification of the discharge and/or storage facilities to the degree where they could safely handle the full p.m.f. There again, it's a state project and we did not incur that obligation under our contracts.

12. We believe the state of Montana can handle #12 through their engineering department and advise us in that regard.

13. We concur that periodic inspection should be conducted and advise that the dam is immediately inspected if a moderate size earthquake occurs within the proximity of the project. We don't know what procedure the state of Montana has developed to notify the water districts in the event of an earthquake, however, in the event the state develops one, we will certainly inspect the dam immediately after any that we are notified of. Of course, the state is aware of the fact that there has been no damage to the dam from past earthquakes in the area, including the severe earthquake in 1959.

14. We certainly object to the removal of any portion of the dam and would hope that the state of Montana would want to preserve this water project, too.

As citizens of the state of Montana, we are relying on the State Department of Natural Resources and its expertise to prevent any hasty decisions that would cause a large expenditure of money before a lot more knowledge and information is gained as to whether the expenditures are reasonably necessary and practical. Everyone is for dam safety, but we cannot live in this world on a statistical basis that something might happen once in 100, 500, or 1,000 years that could cause or create problems with human life or property damage. In order to survive in this world, we

must live with these statistical problems that may or may not catch up with us, including death on the highways, cancer, heart attacks, lung disease, nuclear holocaust, and everything else we do. In the event of the possible, not probable, maximum flood, the damage resulting would occur with or without the Ruby Dam being in place. However, in the meantime, we must go ahead and make a living, provide for our children, pay taxes, and make our water payments and we can't do these things if the state has to comply with the improbable and unreasonable projects made in the above report.

We certainly hope the state will use its best efforts to preserve the beneficial water projects in the state of Montana that were developed for use of its citizens and are certain that they can be looked after in a safe manner as they have in the past. We would hope that the state, with its engineering expertise, will provide answers to this report that will adequately protect the water users that you are selling the water to. After all, the dam was not put in as a money making venture for the state but as a benefit to the state and its citizens and it certainly has been. Every effort should be made to see that it will continue to work.

Respectfully submitted,

RUBY RIVER WATER USERS ASSOCIATION

By Karl L. Lauerkin PRES.

Martin J. Litt Jr. VICE PRES.

Jack Fenton
Directors

VIGILANTE CANAL COMPANY

By Richard L. Todd

Jason Nicholas PRES.

Vernon L Wilson VICE PRES.

Dan D. Conklin
Directors

WEST BENCH CANAL COMPANY

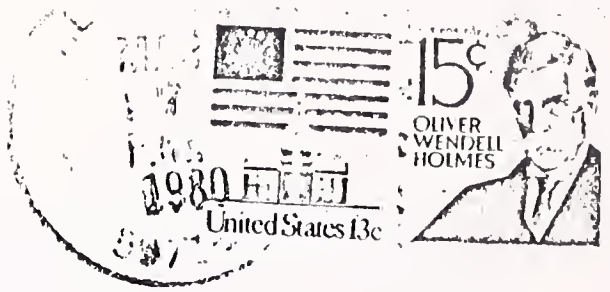
By Jay Burke PRES.

Harold Bell VICE PRES.

Karl L. Lauerkin
Directors

Ruby River Water Users Assn.

ALDER, MONTANA 59710



Mr. Lawrence H. Teeg
Dam Safety Section
Engineering Bureau
Department of Natural Resources
32 South Ewing
Helena, Montana
59601

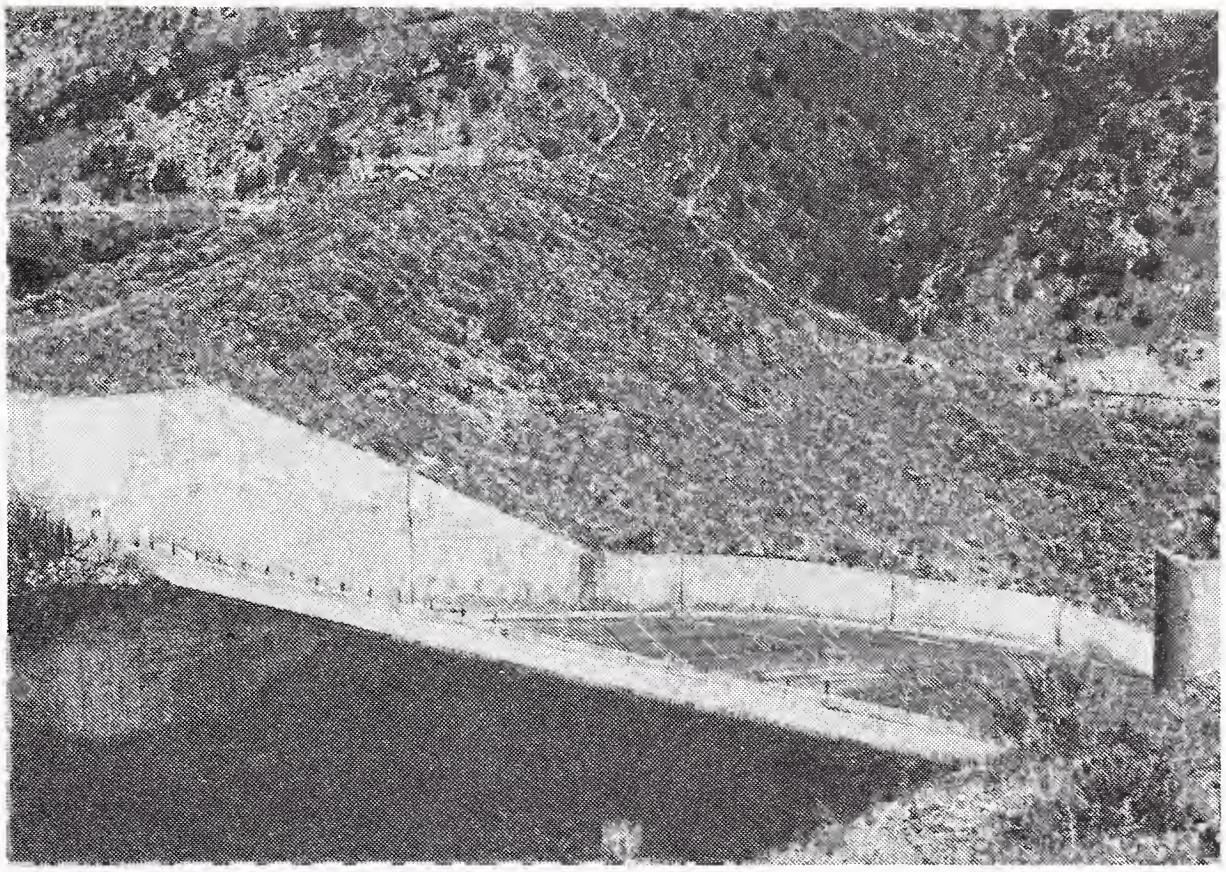


PHOTO 1 Dam and Spillway

PHOTO 2 Spillway Expansion Joint Near Base

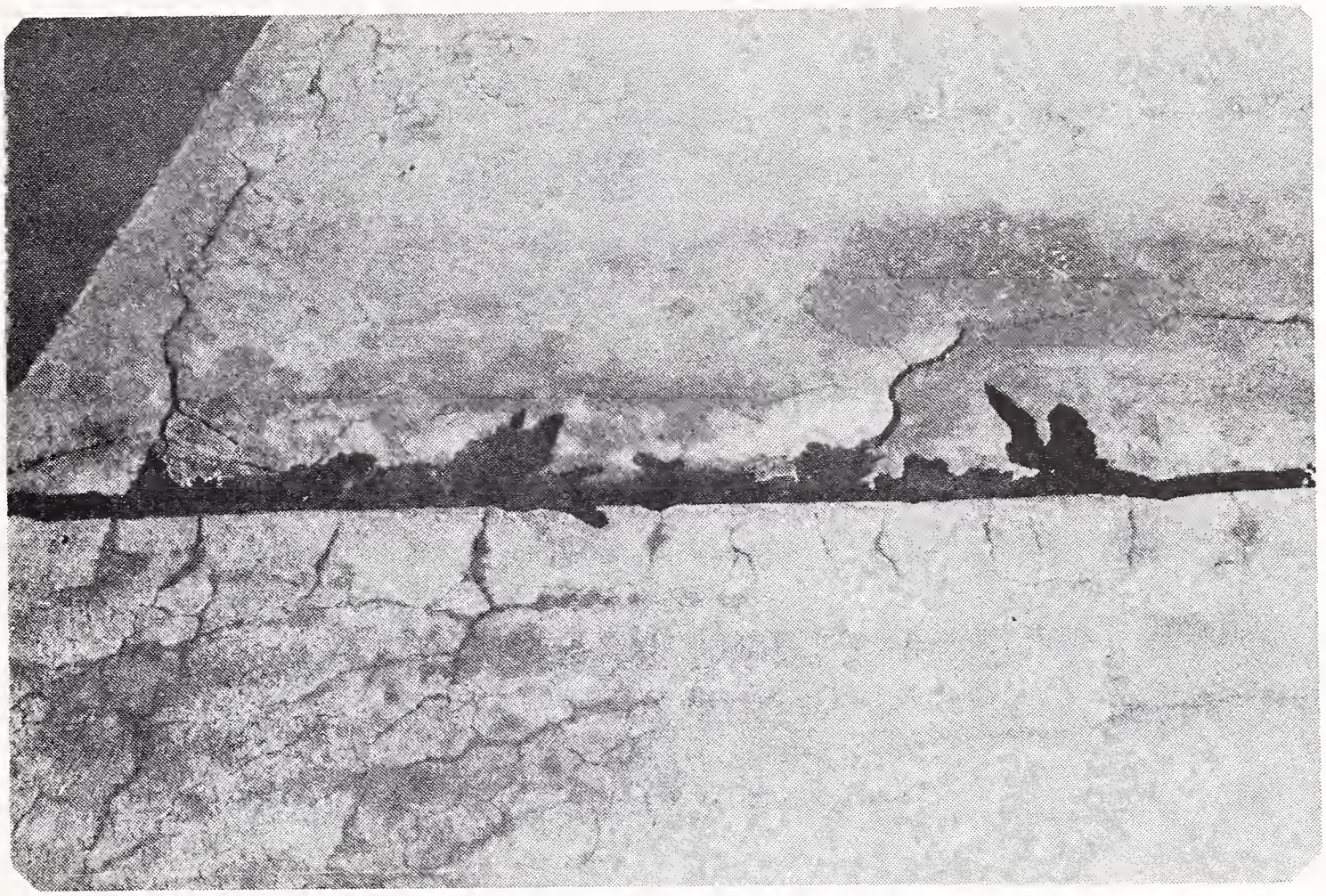


PHOTO 3 Spillway Wall Joint

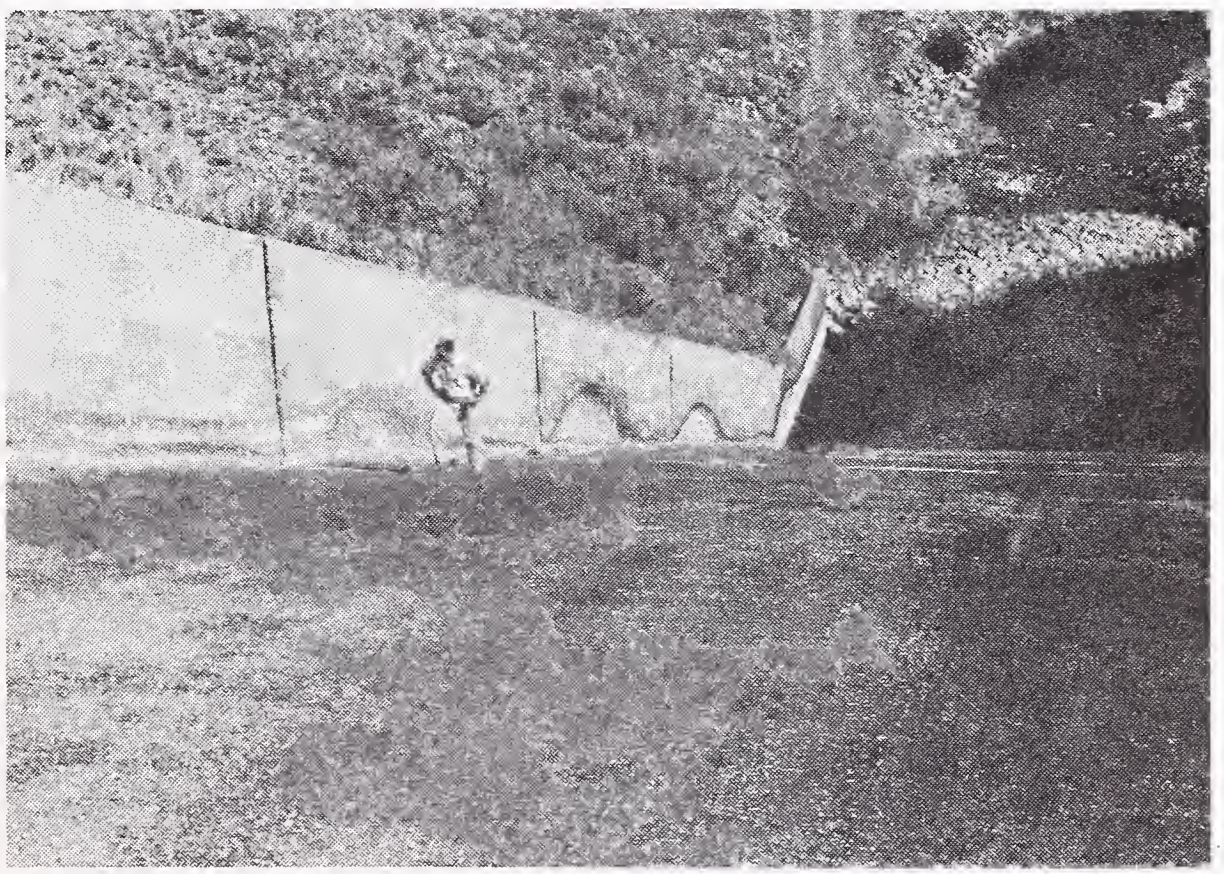


PHOTO 4 Spillway Wall

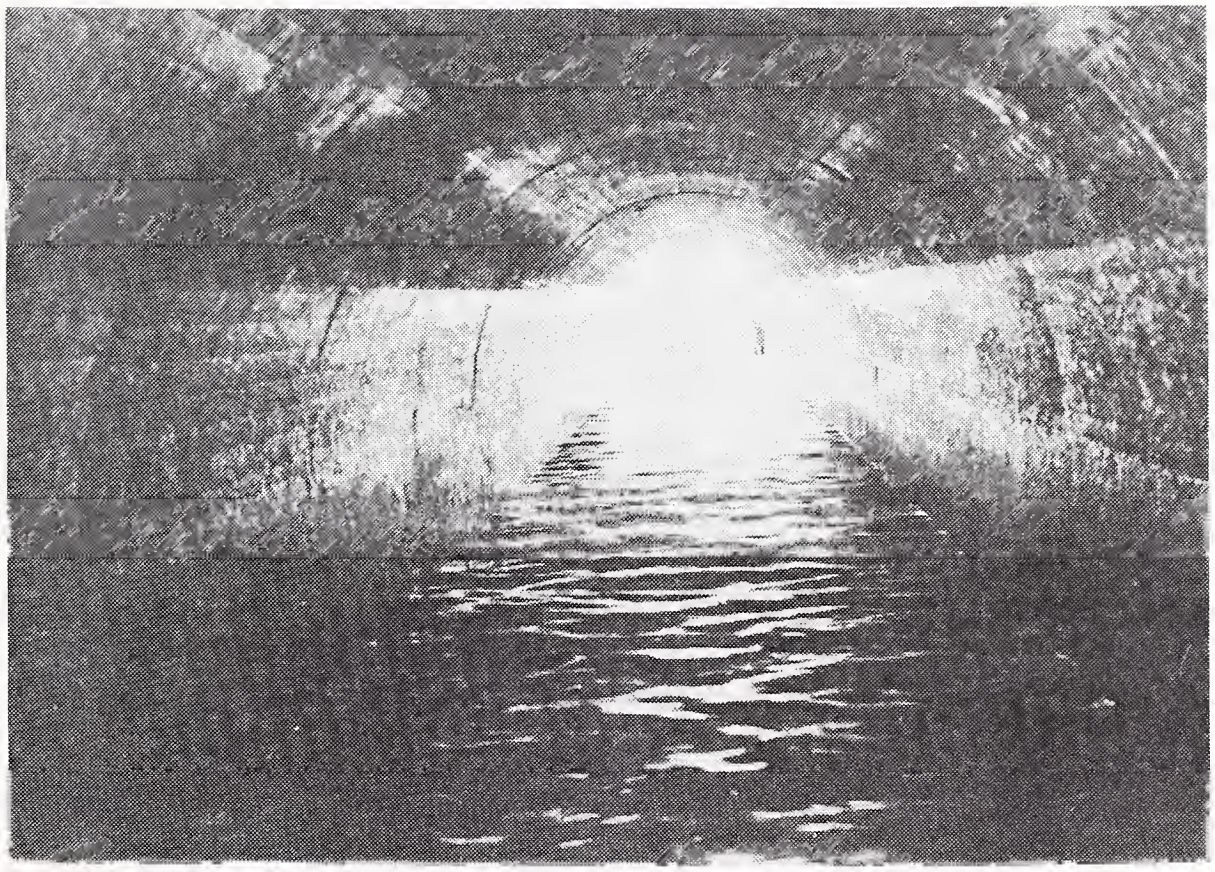


PHOTO 5 Outlet Tunnel Downstream of Tower

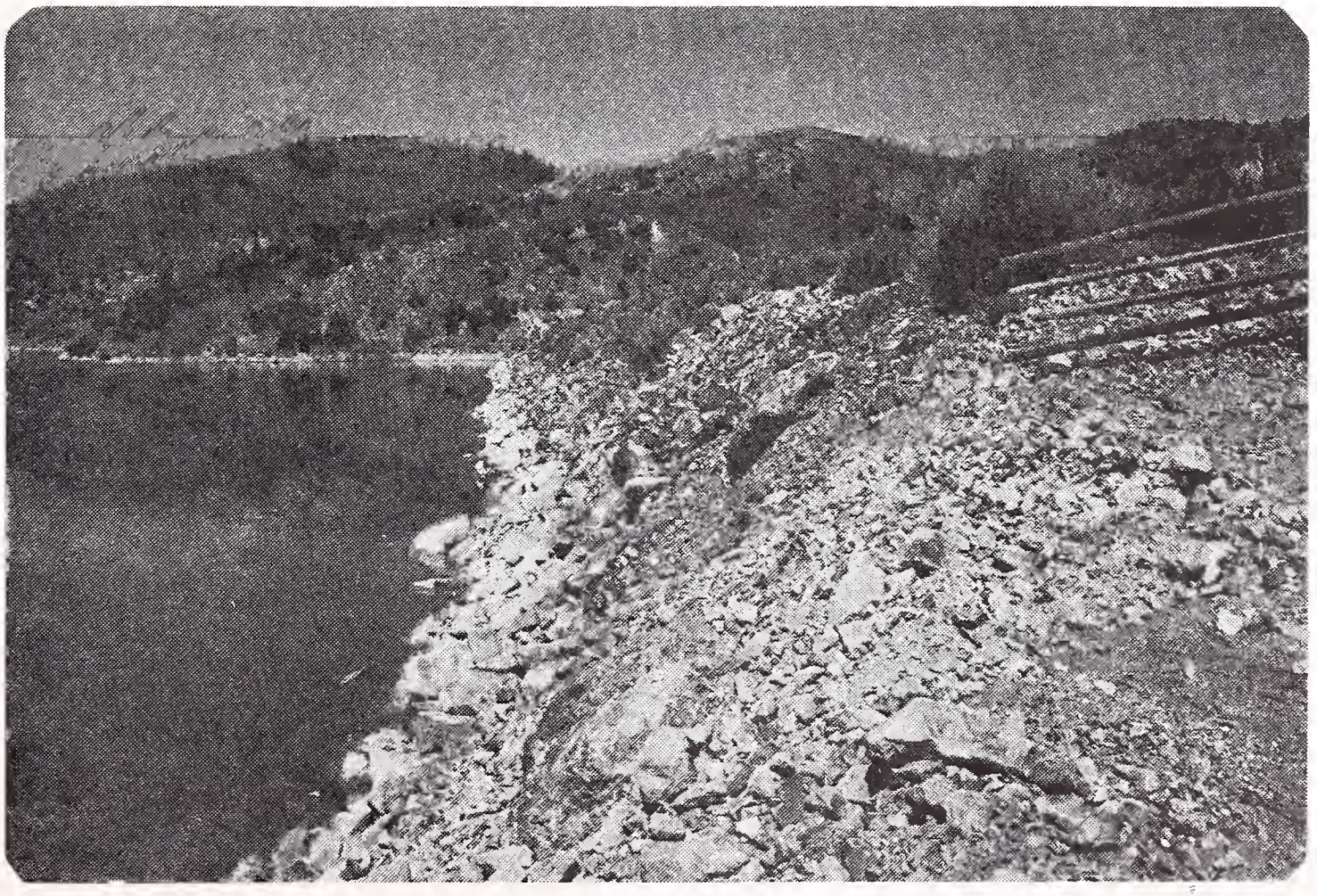


PHOTO 6 Embankment Upstream Slope

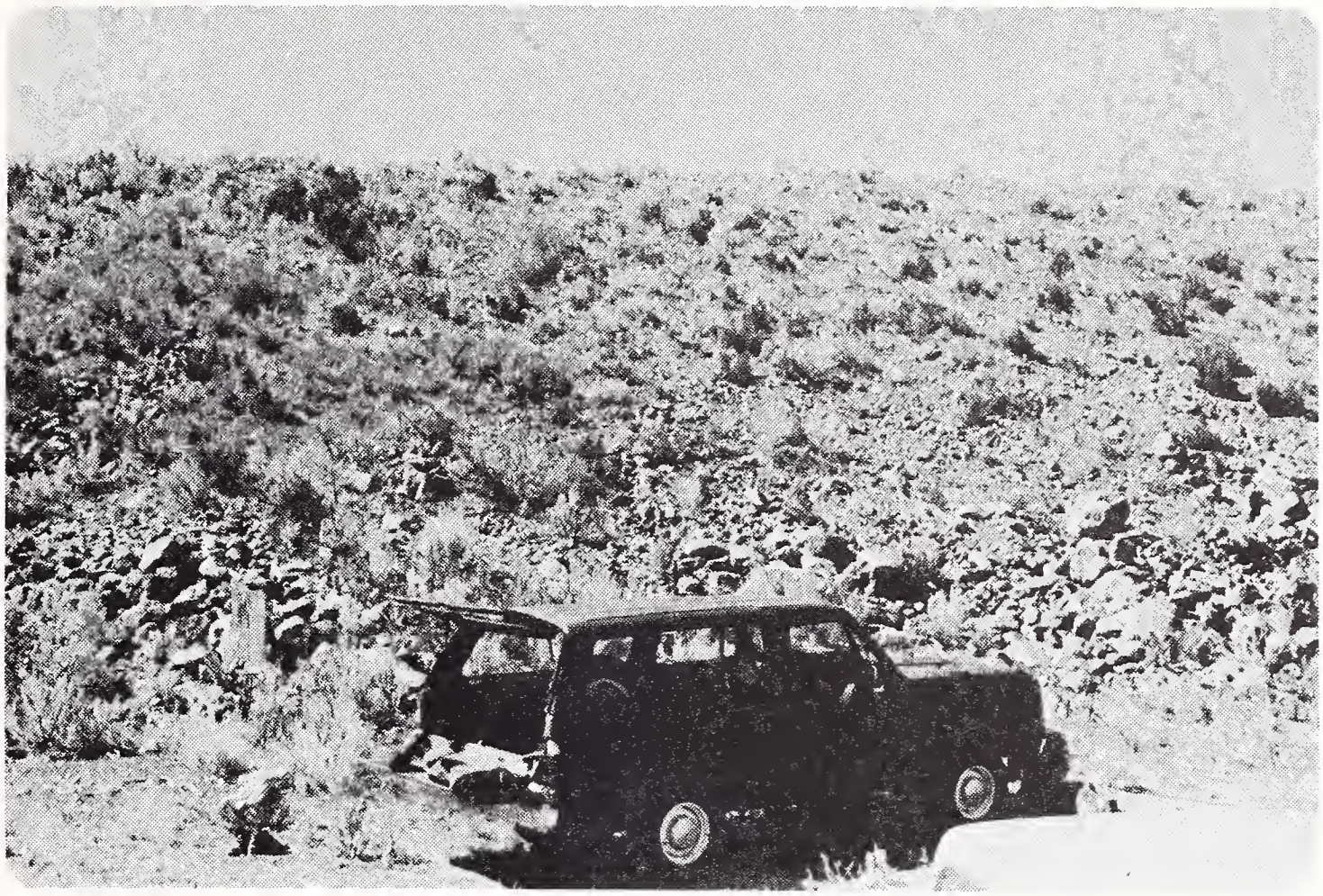


PHOTO 7 Embankment Downstream Slope

TOWN OF ALDER
6 MILES (NORTH)

Ruby

Footbridge

Ruby Dam

SPILLWAY ELEVATION 5392

DAM SITE

ROAD

RUBY RIVER RESERVOIR

UPPER RUBY

RUBY RIVER RESERVOIR SPILLWAY ELEVATION 5392

Warm Springs

Trudau Lake

Kingrey Place

Creek

Tucker Gulch

BM 5419

Dredge Tailings

BM 5394

Idaho

Metzel Ranch

6161

5685

5586

5411

5399

5563

X5750

5700 X

5720 X

5800

6000

5600

5400

5360

5200

7

8

17

18

19

20

30

0 1/2 1 MILE

SCALE 1:24000

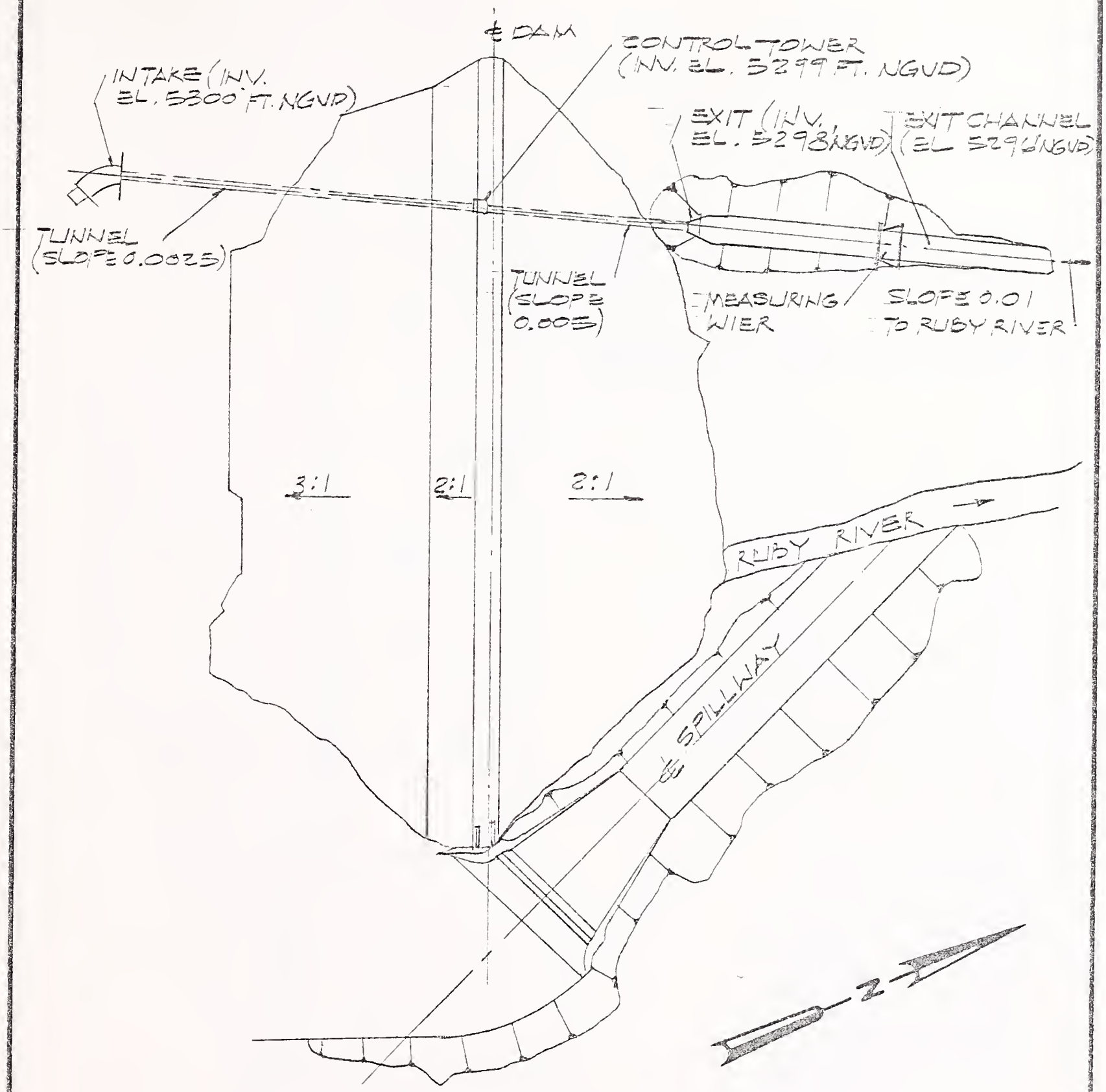
N

PLATE 1

RUBY DAM

VICINITY MAP

CH2M HILL



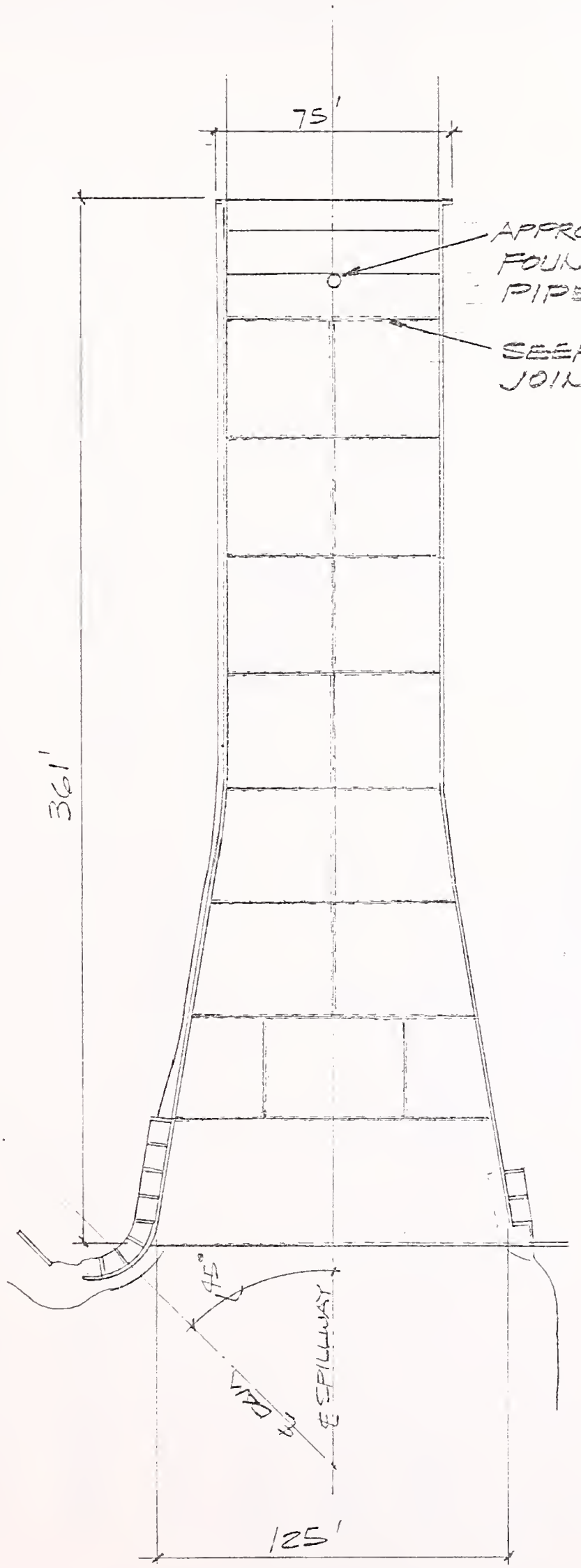
PLAN
N.T.S.

PLATE 2

RUBY RIVER DAM

SITE PLAN

CH2M HILL

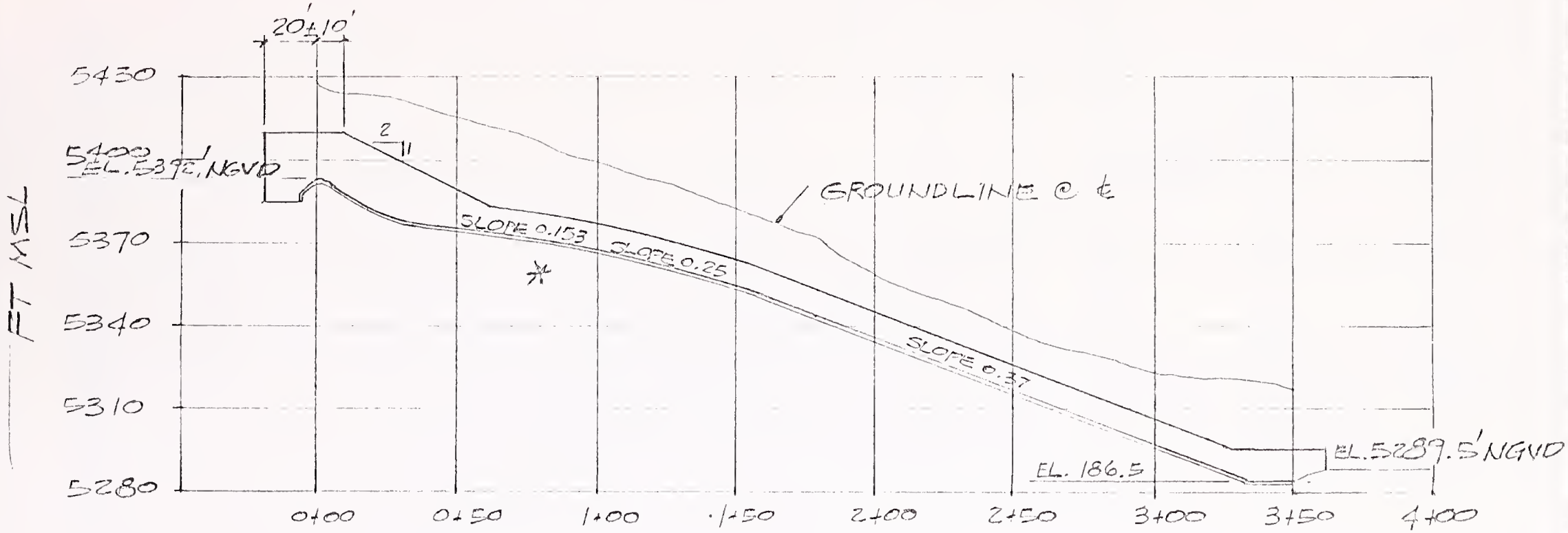


PLAN
N.T.S.

PLATE 3

RUBY RIVER DAM
SPILLWAY PLAN

CH2M HILL



PROFILE
N.T.S.

* CONSTRUCTION PLANS SHOW 6" DRAINS ON CENTERLINE AND CROSS-DRAINS AT CONSTRUCTION JOINTS EXTENDING FROM STA 0+35 TO 3+25, AT WHICH POINT IT DRAINS INTO THE STILLING BASIN.

PLATE 4

RUBY CREEK DAM
SPILLWAY PROFILE

CH2M HILL

DAM CREST ELEVATION 5409.2 FT NGVD

RESERVOIR ELEVATION IN FEET: NGVD

5408
5406
5404
5402
5400
5398
5396
5394
5392

SPILLWAY CREST

0 5000 10000 15000 20000 25000 30000 35000 40000

DISCHARGE, CFS

PLATE 5

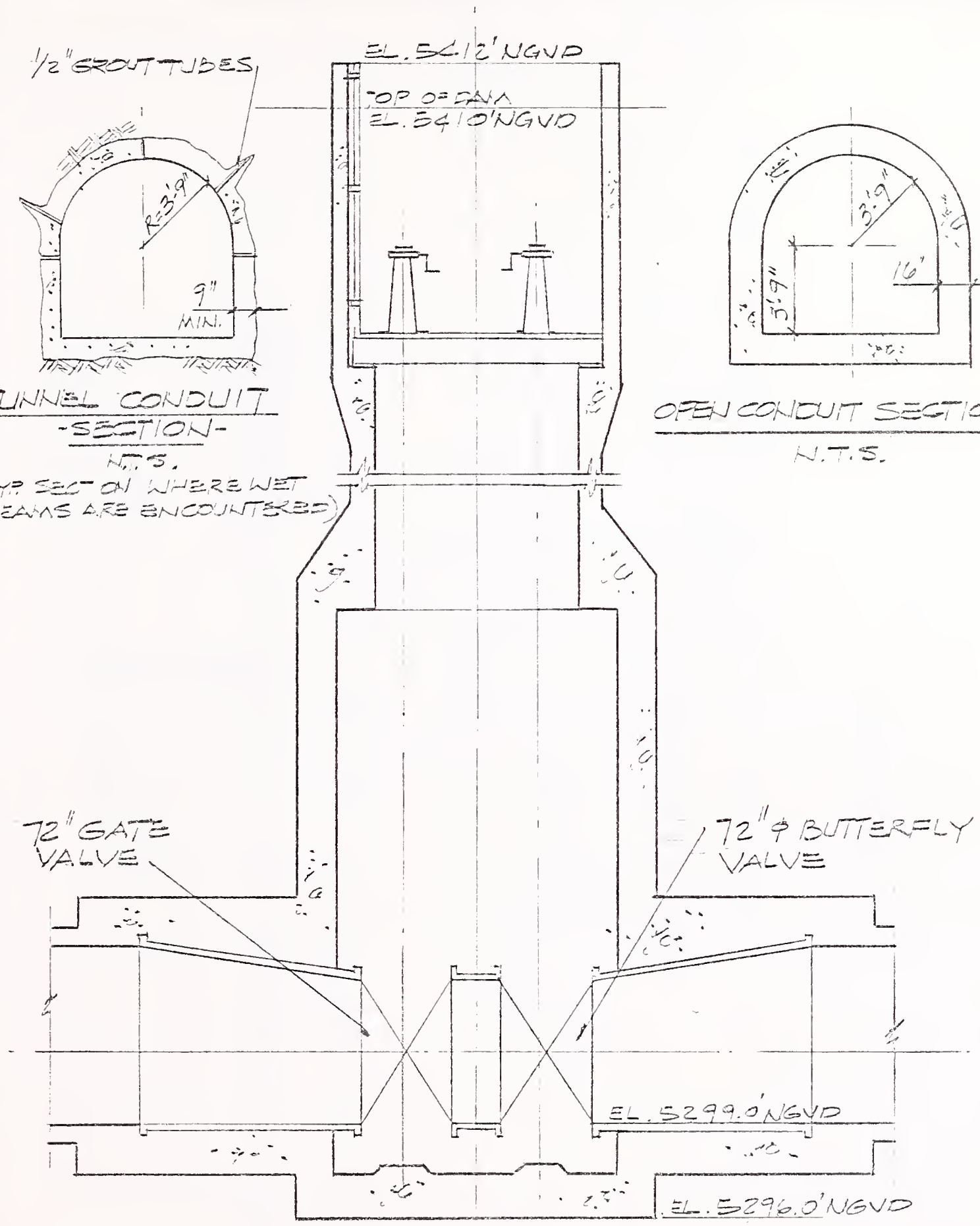
RUBY DAM

SPILLWAY RATING CURVE

CH2M HILL

TUNNEL CONDUIT
-SECTION-
N.T.S.
(TYP. SECTION WHERE WET BEAMS ARE ENCOUNTERED)

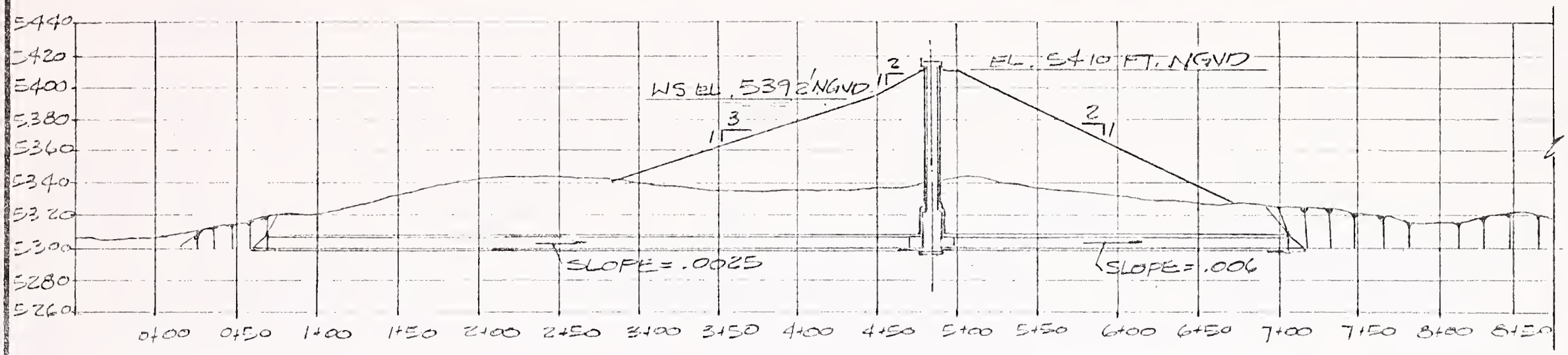
OPEN CONDUIT SECTION
N.T.S.

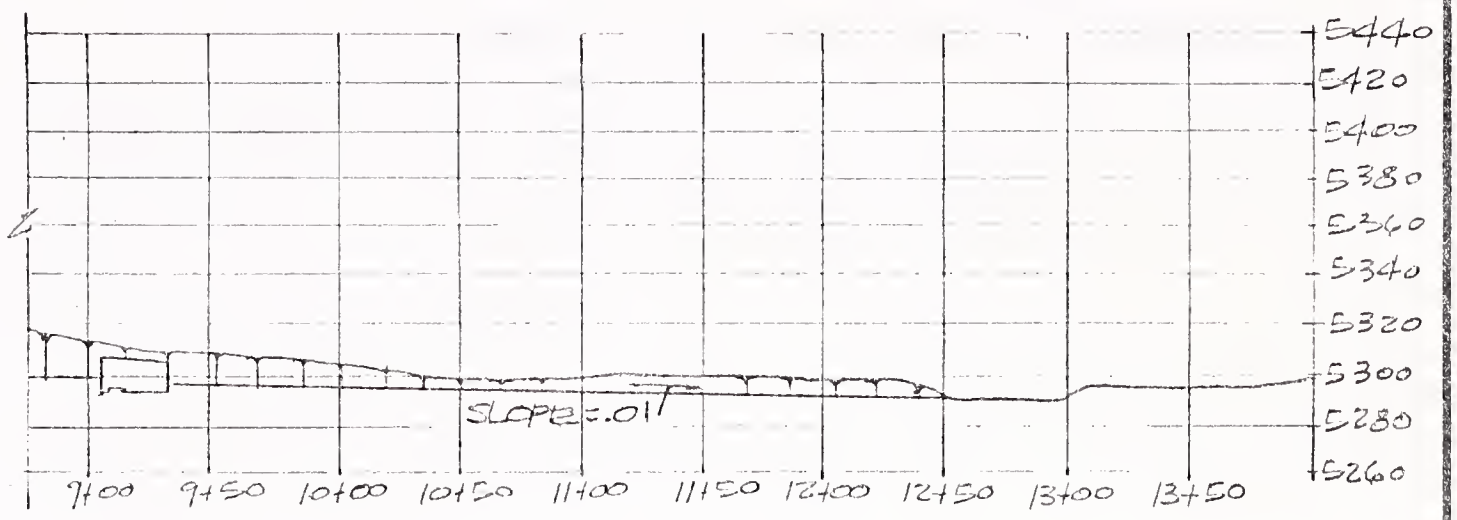


OUTLET WORKS SECTION
N.T.S.

PLATE 6
RUBY CREEK DAM
OUTLET WORKS SECTION

CH2M HILL





PROFILE

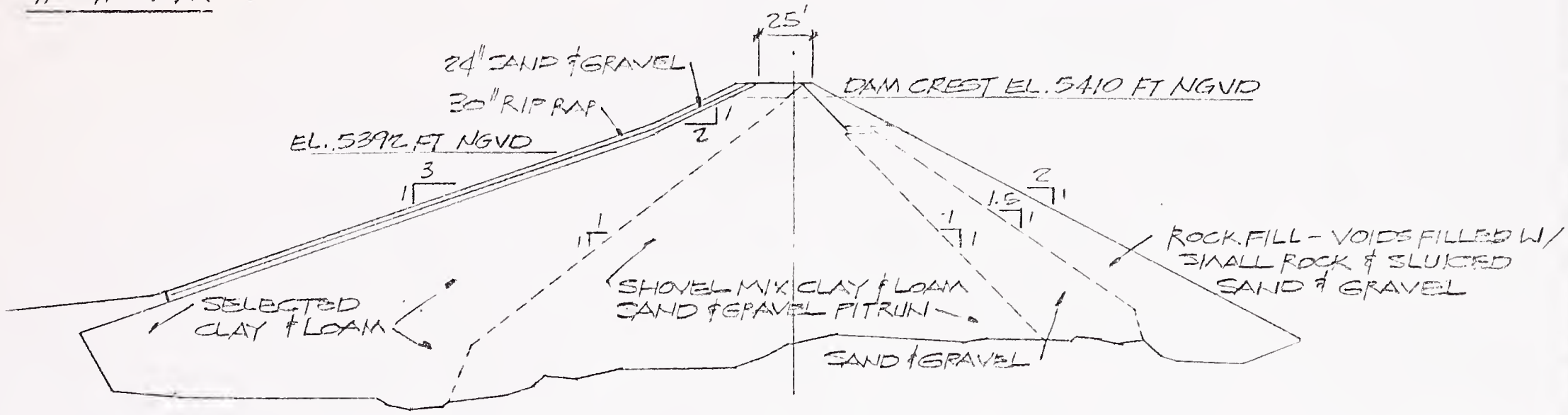
N.T.S.

PLATE 7

RUBY CREEK DAM

OUTLET CONDUIT PROFILE

CH2M HILL



SECTION
N.T.S.

PLATE 3

RUBY CREEK DAM

DAM EMBANKMENT SECTION

CH2M HILL